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Tuttle

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(54) **SYSTEM AND METHOD FOR ACTIVELY DETERMINING A STEERING STOP ANGLE FOR A WORK VEHICLE**

(71) Applicant: **CNH Industrial America, LLC**, New Holland, PA (US)

(72) Inventor: **Thomas Tuttle**, Naperville, IL (US)

(73) Assignee: **CNH Industrial America LLC**, New Holland, PA (US)

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B62D 9/00	(2006.01)
B60G 17/016	(2006.01)
B60G 17/019	(2006.01)
B60G 17/0195	(2006.01)

(52) **U.S. Cl.**

CPC ***B62D 6/002*** (2013.01); ***B60G 17/019*** (2013.01); ***B60G 17/0162*** (2013.01); ***B60G 17/0195*** (2013.01); ***B62D 6/001*** (2013.01); ***B62D 9/00*** (2013.01)

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CPC B62D 6/00; B62D 6/001; B62D 6/002; B60G 17/0162; B60G 17/019; B60G 17/0195

See application file for complete search history.

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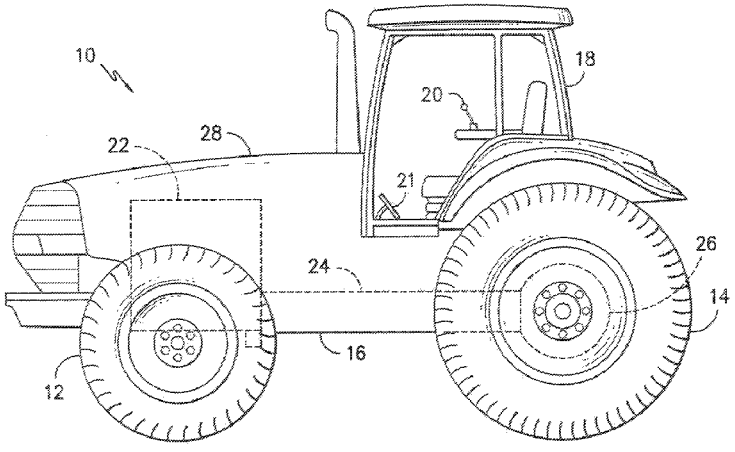
Primary Examiner — Truc M Do
(74) *Attorney, Agent, or Firm* — Rickard K. DeMille; Rebecca L. Henkel

(57) **ABSTRACT**

A method for actively determining a steering stop angle for tires associated with a front axle of a work vehicle may generally include receiving an input associated with a tire parameter for the tires, monitoring a suspension travel distance of the front axle and monitoring an oscillation angle of the front axle. In addition, the method may include determining a maximum allowable steering angle for the tires based on both the suspension travel distance and the oscillation angle of the front axle, wherein the maximum allowable steering angle corresponds to a steering angle at which clearance is maintained between the tires and at least one hood-related component of the work vehicle when the tires are moved to the maximum steering angle.

18 Claims, 10 Drawing Sheets



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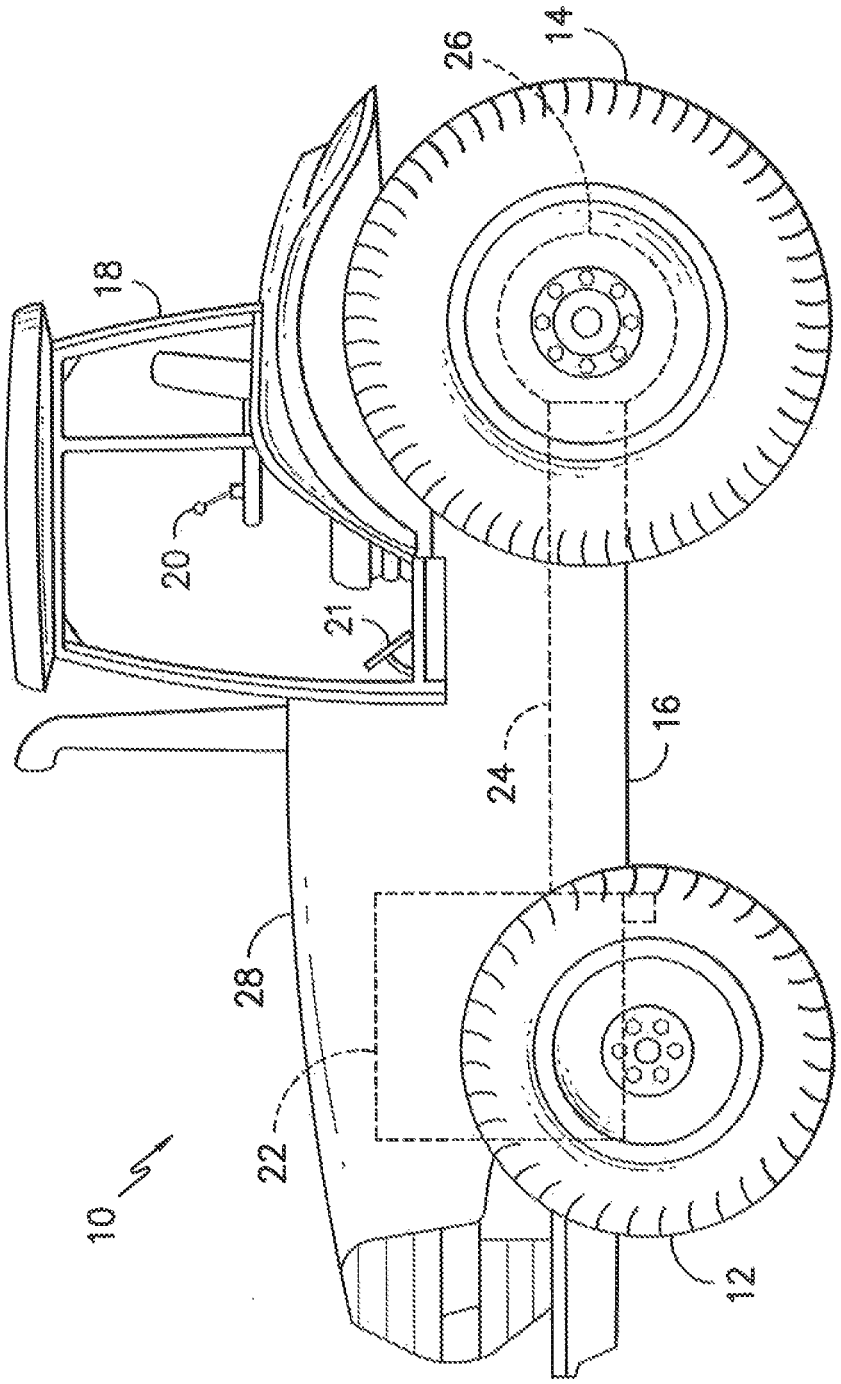


FIG. 1

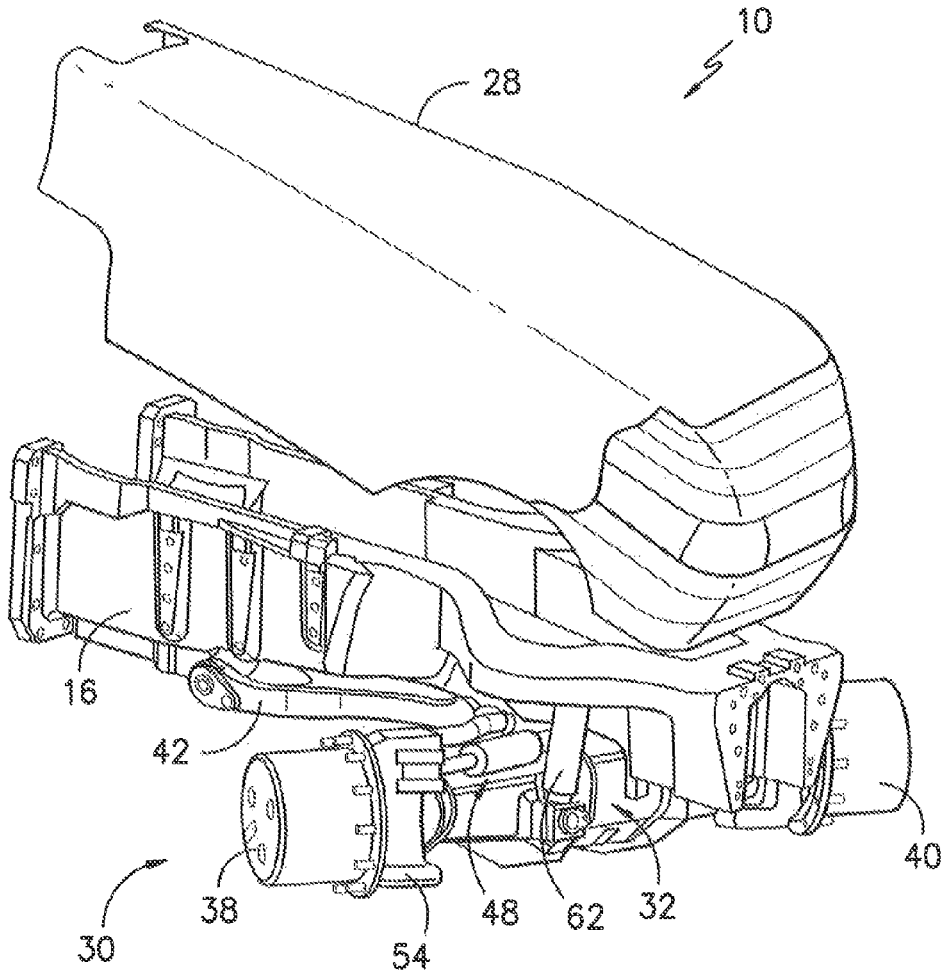


FIG. —2—

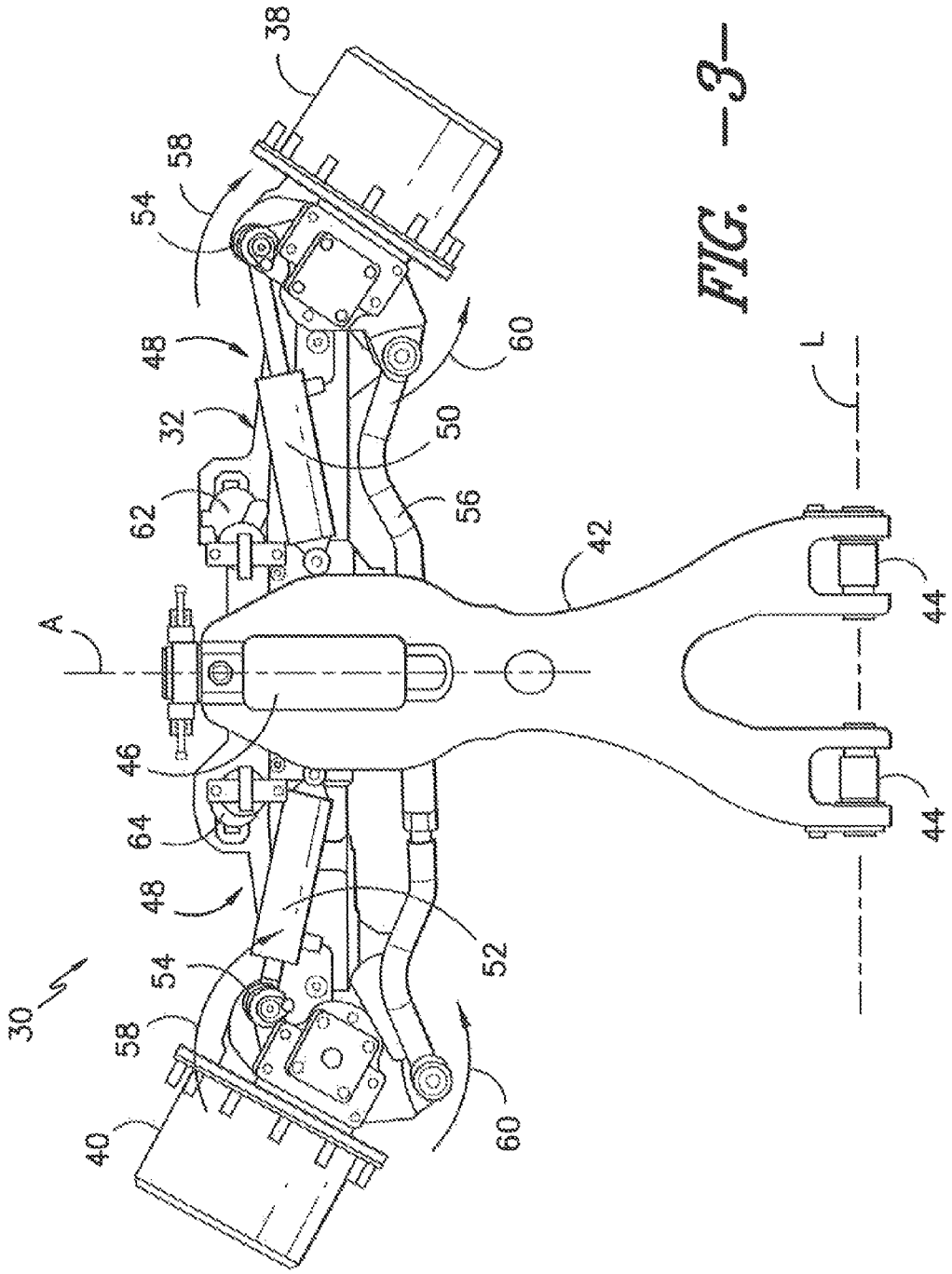


FIG. 3

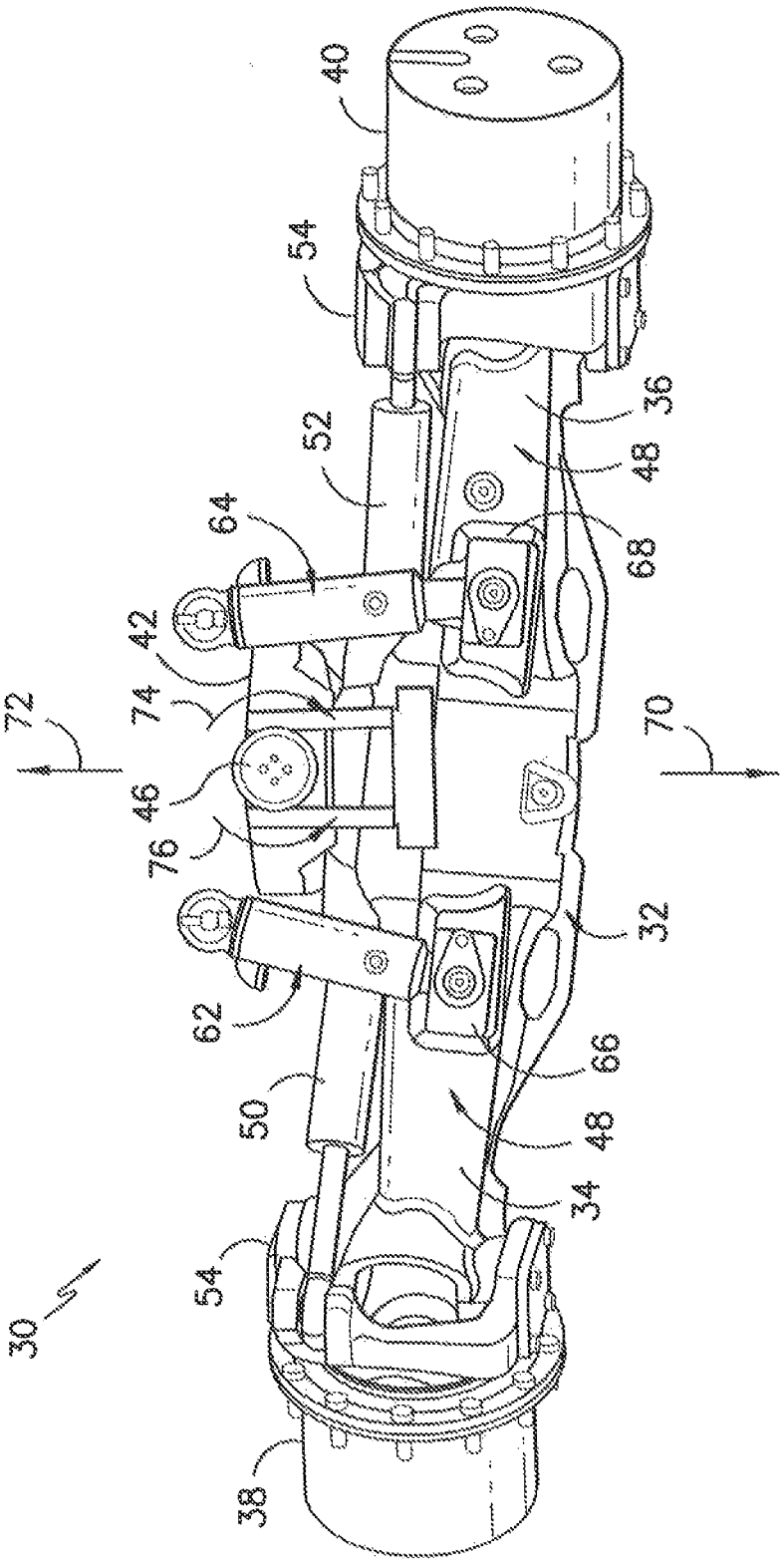


FIG. 4

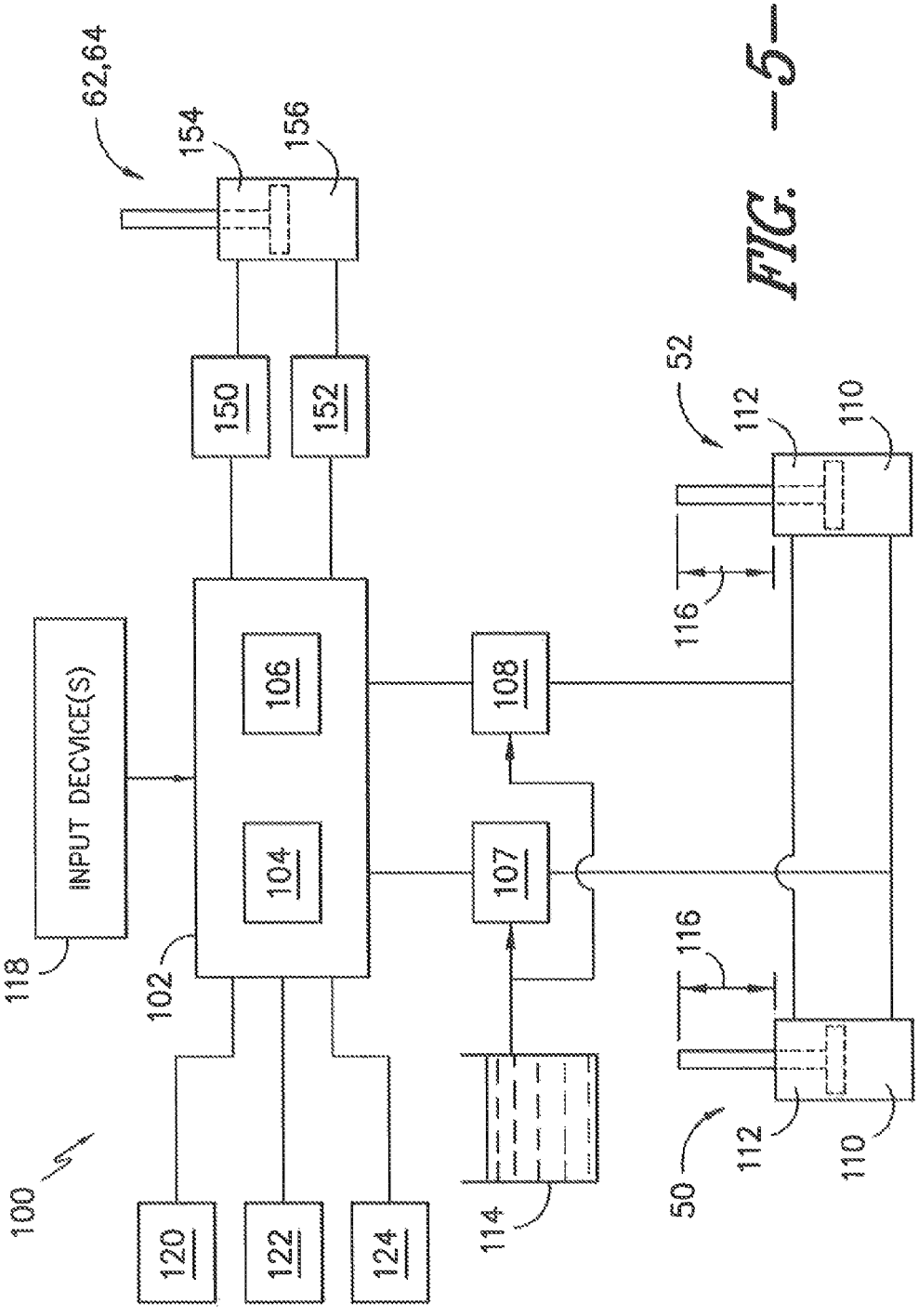

62,64
154
156
150
152
52
112
110
116
INPUT DECVICE(S)
106
108
104
107
118
102
116
100
112
110
50
114
120
122
124

FIG. 5

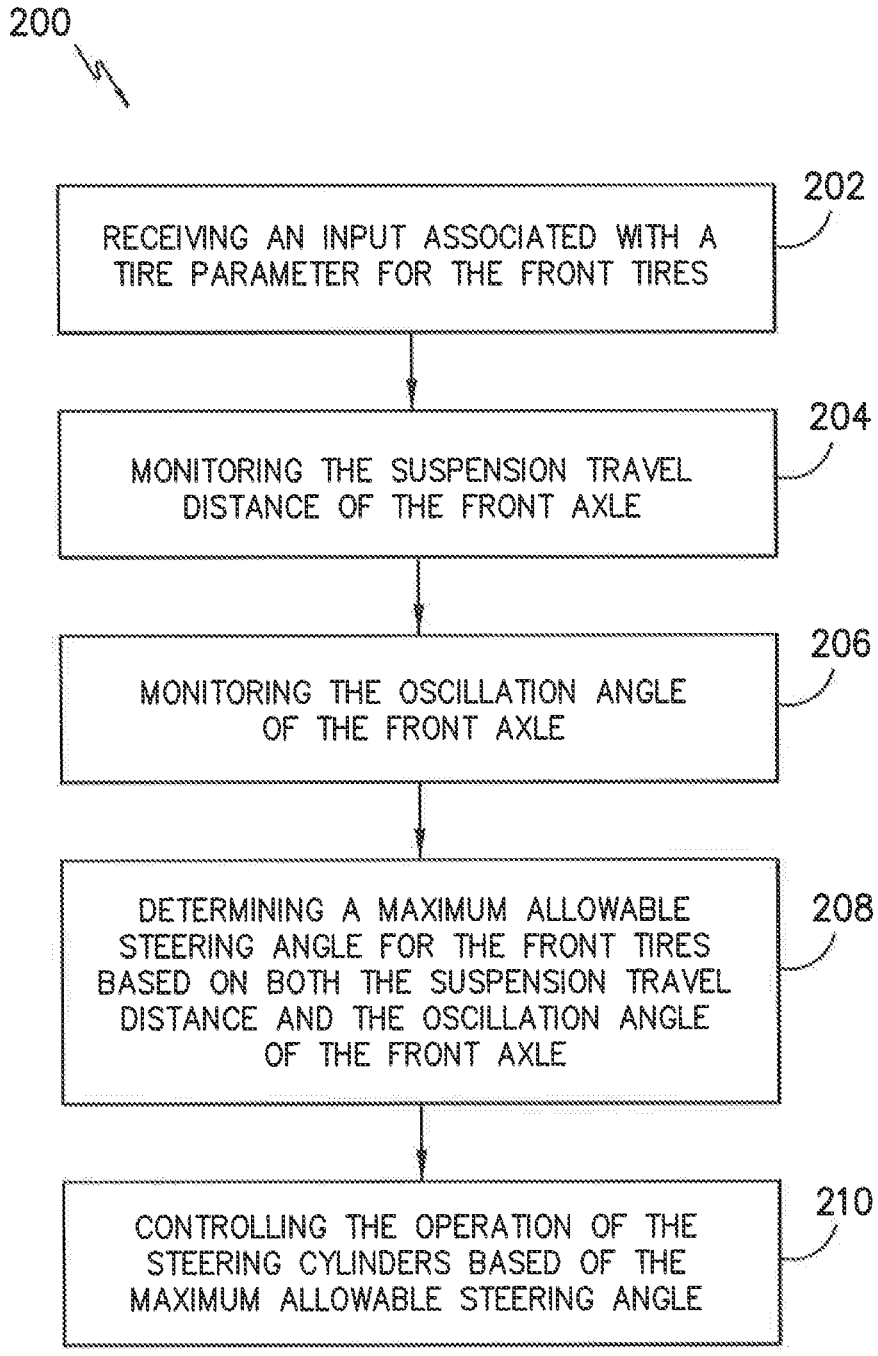
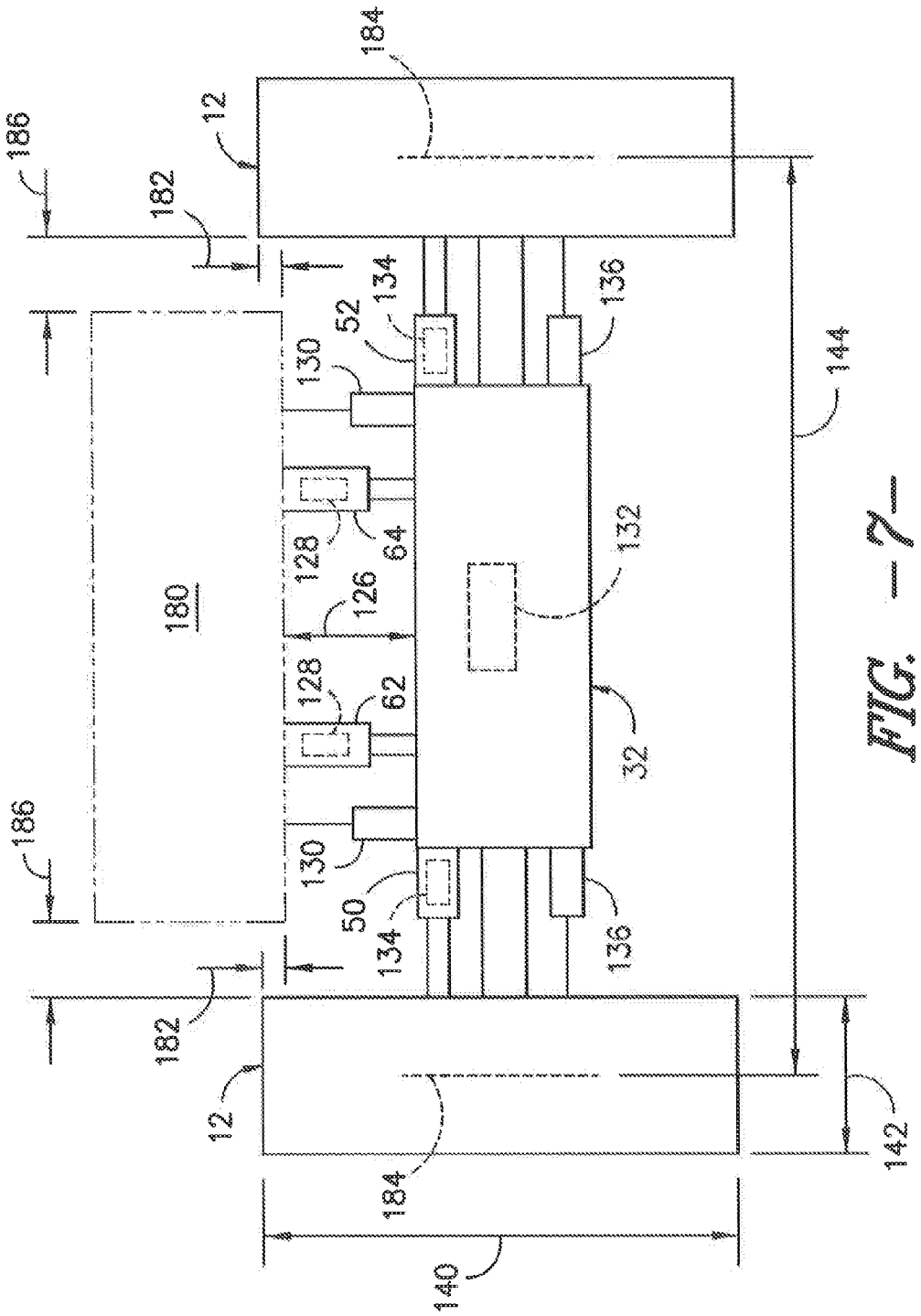

200
RECEIVING AN INPUT ASSOCIATED WITH A TIRE PARAMETER FOR THE FRONT TIRES
202
MONITORING THE SUSPENSION TRAVEL DISTANCE OF THE FRONT AXLE
204
MONITORING THE OSCILLATION ANGLE OF THE FRONT AXLE
206
DETERMINING A MAXIMUM ALLOWABLE STEERING ANGLE FOR THE FRONT TIRES BASED ON BOTH THE SUSPENSION TRAVEL DISTANCE AND THE OSCILLATION ANGLE OF THE FRONT AXLE
208
CONTROLLING THE OPERATION OF THE STEERING CYLINDERS BASED OF THE MAXIMUM ALLOWABLE STEERING ANGLE
210

FIG. —6—


184
12
186
182
134
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136
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144
180
132
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128
126
62
32
50
140
142

FIG. 7

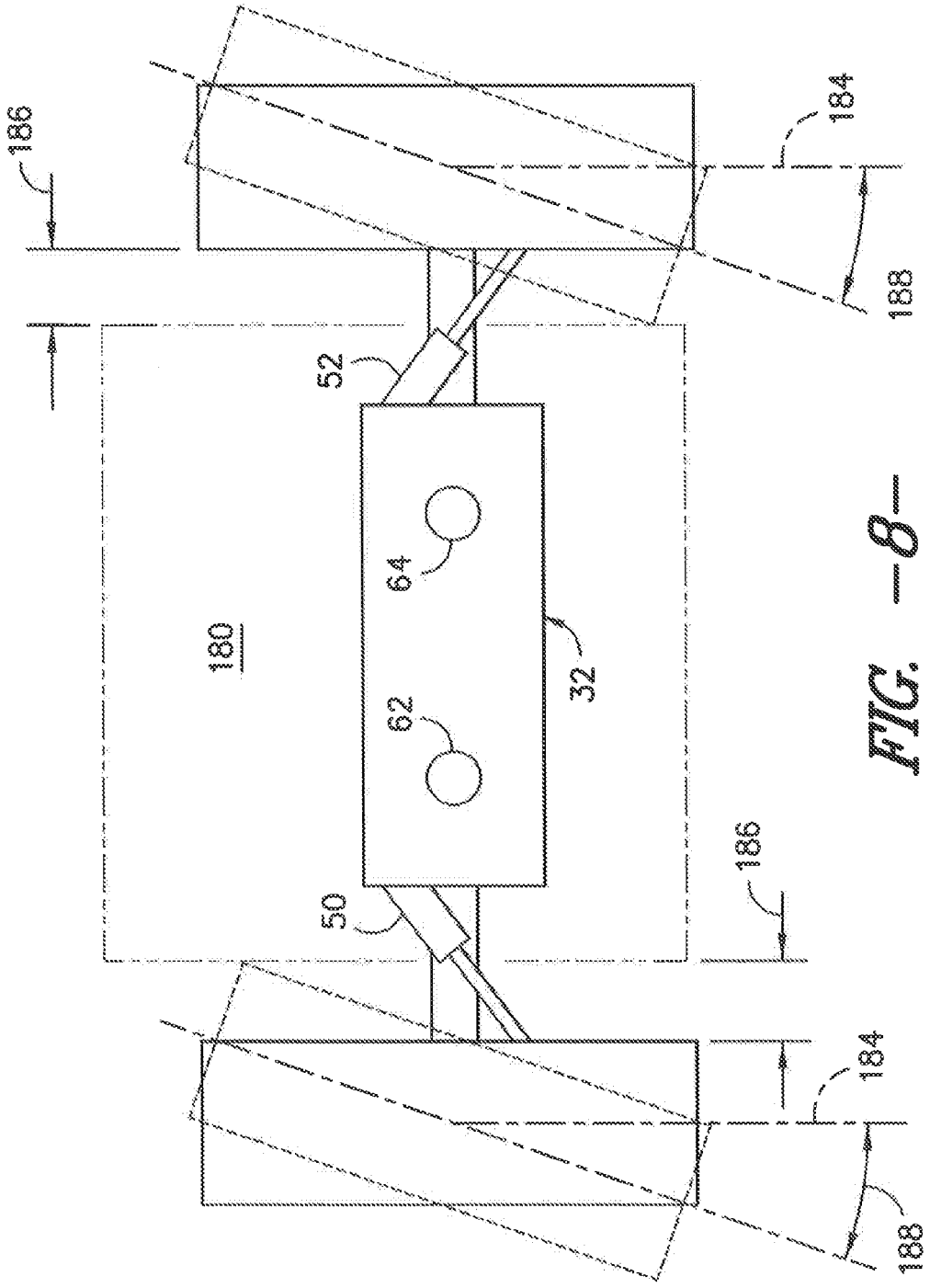


FIG. 8

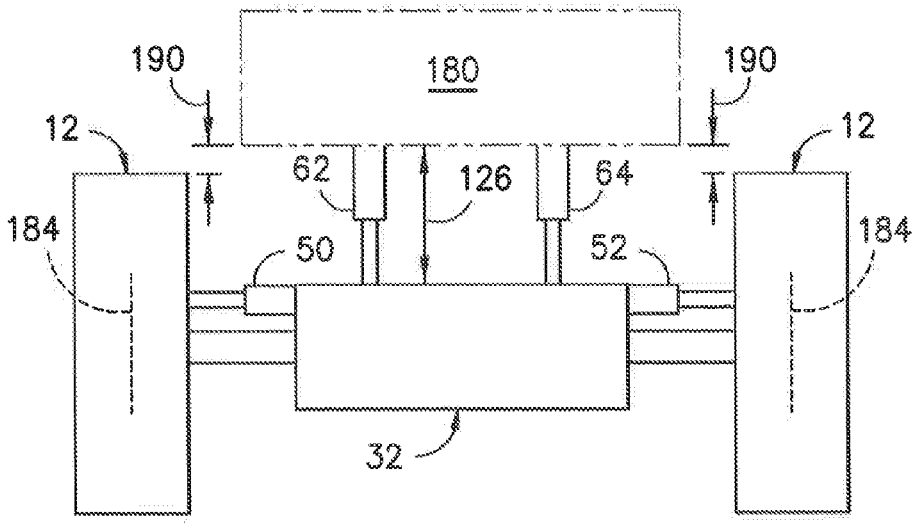

190
180
190
12
12
62
126
64
184
184
50
52
32

FIG. —9—

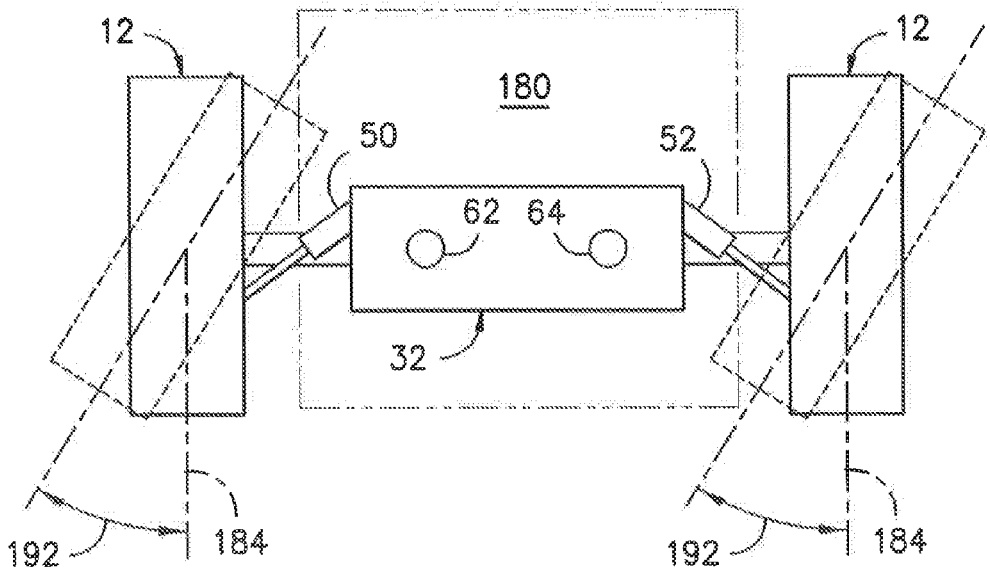
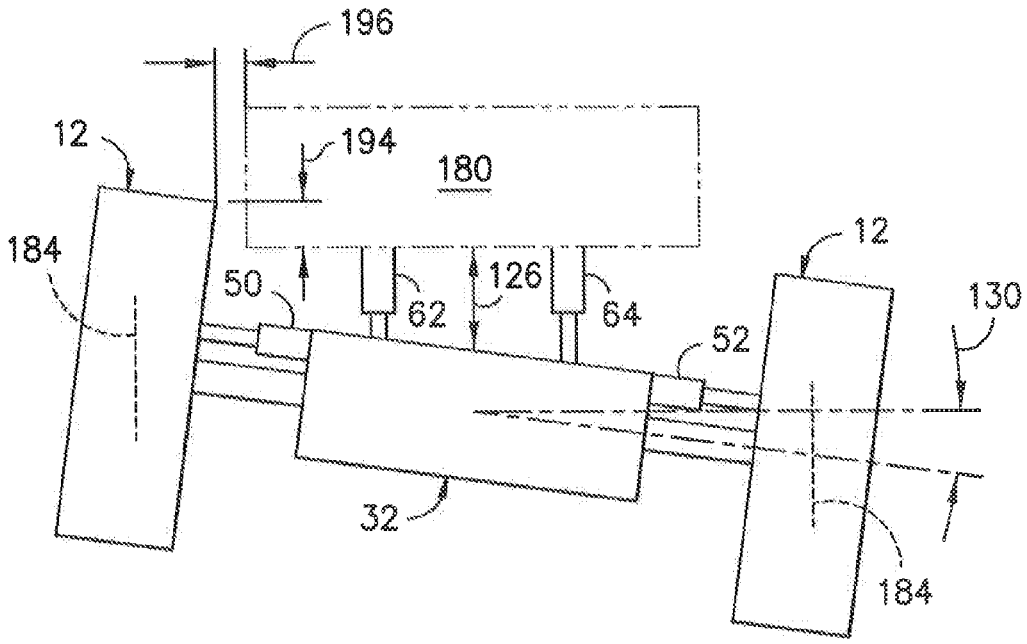

12
12
180
50
52
62
64
32
192
184
192
184

FIG. —10—


196
12
194
180
184
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62
126
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52
12
130
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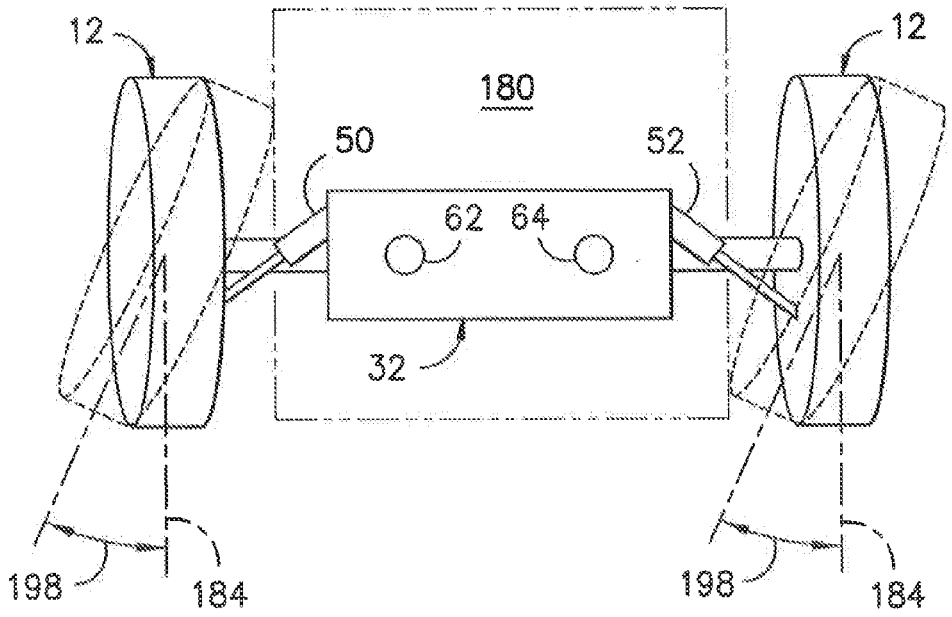
184

FIG. —11—


12
180
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62
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198
184
198
184

FIG. —12—

SYSTEM AND METHOD FOR ACTIVELY DETERMINING A STEERING STOP ANGLE FOR A WORK VEHICLE

FIELD OF THE INVENTION

The present subject matter generally relates to work vehicles and, more particularly, to a system and method for actively determining a steering stop angle for the front tires of a work vehicle having a suspended front axle or any other suitable front axle assembly.

BACKGROUND OF THE INVENTION

Work vehicles, such as tractors and other agricultural vehicles, typically include a suspension system configured to damp vibrations caused by uneven field conditions. The suspension system often includes an axle configured to support one or more wheels on each of its ends and an axle carrier extending between the axle and a frame or chassis of the work vehicle. The axle carrier may generally be configured to rotate relative to the frame about a lateral axis to facilitate vertical movement of the axle. In addition, the axle may be configured to pivot about the axle carrier to enable the axle to oscillate about a substantially longitudinal axis. Moreover, the suspension system may also include actuating cylinders coupled to the axle that are configured to damp vertical and oscillatory movement of the axle, thereby enhancing ride quality, reducing operator fatigue and reducing wear on certain work vehicle components.

Certain work vehicles also include a steering assembly configured to rotate each wheel and, thus, each associated tire relative to the axle across a range of steering angles. To prevent contact and/or damage to the various components positioned adjacent to the tires (e.g., hood, engine, frame, etc.) while the tires are being rotated, conventional steering assemblies typically include mechanical stops that limit both the steering angle of the tires as well as the oscillatory movement of the axle. As a result, the steering performance of work vehicles including such mechanical stops is often quite limited. Moreover, the mechanical stops must be manually adjusted by the operator to accommodate changes in the front-end configuration of the work vehicle (e.g., when larger tires are installed onto the vehicle and/or when the tire tread width of the vehicle is adjusted). Unfortunately, the manner in which the stops must be adjusted can be confusing, which leads to incorrect adjustments resulting in damage to adjacent vehicle components when the tires contact and/or rub against such components while the vehicle is being steered. In addition, the failure to properly adjust the positioning of the stops may also lead to inefficient vehicle operation.

Accordingly, an improved system and method for actively determining a steering stop angle for a work vehicle that allows for the steering performance of the vehicle to be optimized while preventing damage to adjacent vehicle components would be welcomed in the technology.

BRIEF DESCRIPTION OF THE INVENTION

Aspects and advantages of the invention will be set forth in part in the following description, or may be obvious from the description, or may be learned through practice of the invention.

In one aspect, the present subject matter is directed to a method for actively determining a steering stop angle for tires associated with a front axle of a work vehicle. The method may generally include receiving an input associated with a tire parameter for the tires and monitoring a suspension travel distance of the front axle. The suspension travel distance may be associated with a vertical position of the tires relative to at least one hood-related component of the work vehicle. The method may also include monitoring an oscillation angle of the front axle. The oscillation angle may be associated with at least one of the vertical position or a horizontal position of the tires relative to the at least one hood-related component. In addition, the method may include determining a maximum allowable steering angle for the tires based on both the suspension travel distance and the oscillation angle of the front axle, wherein the maximum allowable steering angle corresponds to a steering angle at which clearance is maintained between the tires and the at least one hood-related component when the tires are position at the maximum steering angle.

In another aspect, the present subject matter is directed to a system for actively determining a steering stop angle for tires associated with a front axle of a work vehicle. The system may generally include a controller having a processor and associated memory. The memory may include computer-readable instructions that, when implemented by the processor, configure the controller to receive an input associated with a tire parameter for the tires and monitor a suspension travel distance of the front axle. The suspension travel distance may be associated with a vertical position of the tires relative to at least one hood-related component of the work vehicle. The controller may also be configured to monitor an oscillation angle of the front axle. The oscillation angle may be associated with at least one of the vertical position or a horizontal position of the tires relative to the at least one hood-related component. In addition, the controller may be configured to determine a maximum allowable steering angle for the tires based on both the suspension travel distance and the oscillation angle of the front axle. The maximum allowable steering angle may correspond to a steering angle at which a clearance is maintained between the tires and the at least one hood-related component when the tires are position at the maximum steering angle.

These and other features, aspects and advantages of the present invention will become better understood with reference to the following description and appended claims. The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

A full and enabling disclosure of the present invention, including the best mode thereof, directed to one of ordinary skill in the art, is set forth in the specification, which makes reference to the appended figures, in which:

FIG. **1** illustrates a side view of one embodiment of a work vehicle in accordance with aspects of the present subject matter;

FIG. **2** illustrates a front, perspective view of one embodiment of a suspension system installed under a hood of the work vehicle shown in FIG. **1** in accordance with aspects of the present subject matter;

FIG. **3** illustrates a top view of the suspension system shown in FIG. **2**;

FIG. **4** illustrates a front view of the suspension system shown in FIG. **2**;

FIG. **5** illustrates a schematic view of one embodiment of a system for actively determining a steering stop angle for a work vehicle in accordance with aspects of the present subject matter;

FIG. **6** illustrates a flow diagram of one embodiment of a method for actively determining a steering stop angle for a work vehicle in accordance with aspects of the present subject matter;

FIG. **7** illustrates a schematic, front view of a front axle and front tires of a work vehicle in accordance with aspects of the present subject matter, particularly illustrating the positioning of the front tires relative to a hood-related component of the work vehicle;

FIG. **8** illustrates a schematic, top view of the vehicle components shown in FIG. **7**, particularly illustrating the steering angle at which the front tires contact the hood-related component due to the relative positioning of such components;

FIG. **9** illustrates another schematic, front view of the vehicle components shown in FIG. **7**, particularly illustrating the positioning of the front tires relative to the hood-related component after the suspension travel distance of the front axle has changed;

FIG. **10** illustrates a schematic, top view of the vehicle components shown in FIG. **9**, particularly illustrating an example of a steering angle that may be achieved due to the relative positioning of such components;

FIG. **11** illustrates another schematic, front view of the vehicle components shown in FIG. **7**, particularly illustrating the positioning of the front tires relative to the hood-related component after the oscillation angle of the front axle has changed; and

FIG. **12** illustrates a schematic, top view of the vehicle components shown in FIG. **11**, particularly illustrating the steering angle at which the front tires contact the hood-related component due to the relative positioning of such components.

DETAILED DESCRIPTION OF THE INVENTION

Reference now will be made in detail to embodiments of the invention, one or more examples of which are illustrated in the drawings. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope or spirit of the invention. For instance, features illustrated or described as part of one embodiment can be used with another embodiment to yield a still further embodiment. Thus, it is intended that the present invention covers such modifications and variations as come within the scope of the appended claims and their equivalents.

In general, the present subject matter is directed to a system and method for actively determining a steering stop angle for a work vehicle. Specifically, in several embodiments, a controller of the work vehicle may be configured to actively monitor one or more axle-related parameters associated with a front axle of the vehicle. For instance, as will be described below, the controller may be configured to continuously monitor both a suspension travel distance and an oscillation angle of the front axle as the work vehicle is being operated. Based on such monitored parameters, along with inputs received related to one or more fixed tire parameters (e.g., tire size and/or tire tread width), the controller may be configured to determine a maximum allowable steering angle to which the vehicle's front tires may be rotated without contacting a hood-related component of the work vehicle (e.g., the hood and/or a under-hood component of the vehicle). The controller may then be configured to control the operation of a steering assembly of the work vehicle in a manner that prevents the front tires from being rotated beyond the maximum allowable steering angle determined for the front tires.

It should be appreciated that, in several embodiments, the controller may also be configured to monitor one or more vehicle parameters of the work vehicle, such as the vehicle's ground speed. For instance, a slow ground speed may provide an indication that the vehicle is performing work (e.g., field work) in which optimized steering is desirable whereas higher ground speeds (e.g., during road transport) may provide an indication that optimized steering is not critical. Thus, by monitoring the ground speed, the controller may be configured to adapt its control of the various vehicle components.

Additionally, in several embodiments, the controller may also be configured to actively control the vehicle's suspension cylinders in order to limit the suspension travel distance and/or the oscillation angle of the front axle in a manner that prevents contact between the tires and any adjacent hood-related components. For instance, while a work vehicle is in the process of turning, its front tires may be positioned at a steering angle that is less than the maximum allowable steering angle determined based on the current suspension travel distance and oscillation angle of the front axle. However, if a given change in the suspension travel distance and/or the oscillation angle would cause the front tires to contact any of the adjacent hood-related components, the controller may be configured to limit and/or adjust the suspension travel distance and/or the oscillation angle of the front axle by actively controlling the operation of the suspension cylinders in a manner that prevents such contact.

Referring now to the drawings, FIG. **1** illustrates a side view of one embodiment of a work vehicle **10** in accordance with aspects of the present subject matter. As shown, the work vehicle **10** is configured as an agricultural tractor. However, in other embodiments, the work vehicle **10** may be configured as any other suitable work vehicle known in the art, such as various other agricultural vehicles, earth-moving vehicles, loaders and/or various other off-road vehicles.

As shown in FIG. **1**, the work vehicle **10** includes a pair of front wheels (and associated front tires **12**), a pair or rear wheels (and associated rear tires **14**) and a frame or chassis **16** coupled to and supported by the wheels. However, in other embodiments, the work vehicle **10** may include two or more pairs of front tires **12** and/or two or more pairs of rear tires **14**, such as in the case of a dual or triple tire configuration. An operator's cab **18** may be supported by a portion of the chassis **16** and may house various input devices **20**, **21** for permitting an operator to control the operation of the work vehicle **10**. Additionally, the work vehicle **10** may include an engine **22** and a transmission **24** mounted on the chassis **16**. The transmission **24** may be operably coupled to the engine **22** and may provide variably adjusted gear ratios for transferring engine power to the wheels via a drive axle assembly **26**.

The work vehicle **10** may also include a hood **28** extending from the cab **18** towards the front end of the vehicle **10**. As is generally understood, the hood **28** may be configured to house the engine **22** and various other under-hood components of the work vehicle **10** (e.g., various hydraulic systems, pneumatic systems, electrical systems, mechanical systems, fluid storage tanks and/or the like). For instance, as

will be described below, a suspension system **30** (FIGS. **2-4**) may be disposed under the hood **28** that allows for a front axle **32** of the work vehicle **10** to move relative to the chassis **16**. Specifically, the suspension system **30** may be configured such that the front axle **32** is capable of moving vertically relative to the chassis **16** as well as pivoting or oscillating relative to the chassis **16**, thereby providing a means for damping both vertical and oscillatory movement of the front axle **32**.

It should be appreciated that the configuration of the work vehicle **10** described above and shown in FIG. **1** is provided only to place the present subject matter in an exemplary field of use. Thus, it should be appreciated that the present subject matter may be readily adaptable to any manner of work vehicle configuration **10**. For example, in an alternative embodiment, a separate frame or chassis may be provided to which the engine **22**, transmission **24**, and drive axle assembly **26** are coupled, a configuration common in smaller tractors. Still other configurations may use an articulated chassis to steer the work vehicle **10**, or rely on tracks in lieu of the tires **12**, **14**. Additionally, although not shown, the work vehicle **10** may also be configured to be operably coupled to any suitable type of work implement, such as a trailer, spray boom, manure tank, feed grinder, plow and/or the like.

Referring now to FIG. **2-4**, a several views of one embodiment of a suspension system **30** suitable for use with the work vehicle **10** shown in FIG. **1** is illustrated in accordance with aspects of the present subject matter. Specifically, FIG. **2** illustrates a front, perspective view of the suspension system **30** installed under the hood **28** of the work vehicle **10**. Additionally, FIGS. **3** and **4** illustrate top and front views, respectively, of the suspension system **30**.

As shown, the suspension system **30** may include a front axle **32** extending between a first lateral end **34** (FIG. **4**) and a second lateral end **36** (FIG. **4**). In general, the front axle **32** may be configured to support a first front tire **12** of the work vehicle **10** at the first lateral end **34** and a second front tire **12** of the work vehicle **10** at the second lateral end **36**. As shown in the illustrated embodiment, first and second hubs **38**, **40** may be disposed at the first and second lateral ends **34**, **36** for coupling the tires **12** to the front axle **32**.

The suspension system may also include an axle carrier **42** configured to extend between the chassis **16** and the front axle **32**. In general, the axle carrier **42** may be configured to rotate relative to the chassis **16** about a lateral axis L (FIG. **3**) to facilitate vertical movement of the front axle **32** relative to chassis **16**. For example, as particularly shown in FIG. **3**, the axle carrier **42** may include pins **44** configured to rotatably couple the axle carrier **42** to the chassis **16**, thereby allowing the axle carrier **42** to rotate relative to the chassis **16** about the lateral axis L. In addition, as shown in FIGS. **3** and **4**, the axle carrier **42** may be configured to be coupled to the front axle **32** via a pin **46** to allow the front axle **32** to pivot or oscillate relative to the axle carrier **42** (and, thus, the chassis **16**) about a longitudinal axis A (FIG. **3**). As is generally understood, by allowing such vertical and oscillatory movement of the front axle **32** relative to the chassis **16**, the associated work vehicle **10** may be configured to traverse uneven terrain while maintaining contact between the tires **12** and the ground.

In addition, the suspension system **30** may also include a steering assembly **48** configured to rotate each tire **12** relative to the front axle **32** about a substantially vertical axis. As shown in the illustrated embodiment, the steering assembly **48** may include a first steering cylinder **50** and a second steering cylinder **52**. In general, each steering cylinder **50**, **52** may be configured to extend between a central portion of the axle **32** and a knuckle **54** rotatably coupled to each lateral end **34**, **36** of the axle **32**. In addition, the steering assembly **48** may also include a tie rod **56** extending between the knuckles **54** to facilitate synchronized rotation of the tires **12** relative to the front axle **32**.

As is generally understood, the steering assembly **48** may be configured to drive each knuckle **54** to rotate about a kingpin (not shown), which, in turn, rotates the hubs **38**, **40** and, thus, the attached front tires **12** of the work vehicle **10**. For example, as shown in FIG. **3**, extension of a piston rod of the first steering cylinder **50** and retraction of a piston rod of the second steering cylinder **52** may induce the front tires **12** to rotate in a clockwise direction **58** across a given range of steering angles. Conversely, retraction of the piston rod of the first steering cylinder **50** and extension of the piston rod of the second steering cylinder **52** may induce the tires **12** to rotate in a counter-clockwise direction **60** across a given range of steering angles. As will be described below, by limiting the operation of the steering cylinders **50**, **52** based on a determined steering stop angle (or maximum allowable steering angle) for the front tires **12**, the work vehicle **10** may be steered while maintaining clearance between the tires **12** and one or more hood-related components of the vehicle **10**.

In addition, the suspension system **30** may also include first and second suspension cylinders **62**, **64** coupled between the font axle **32** and the chassis **16**. Specifically, as shown in FIG. **4**, the first suspension cylinder **62** may include a first end configured to be coupled to a first lateral side **66** of the front axle **32** and may extend upwardly to a second end configured to be coupled to the chassis **16**. Similarly, the second suspension cylinder **64** may include a first end configured to be coupled to a second lateral side **68** of the front axle **32** and may extend upwardly to a second end configured to be coupled to the chassis **16**.

As is generally understood, extension of the piston rods associated with the first and second suspension cylinders **62**, **64** may induce the front axle **32** to move vertically downward (indicated by arrow **70** of FIG. **4**) relative to the chassis **16** while retraction of the piston rods may induce the front axle **32** to move vertically upward (indicated by arrow **72** of FIG. **4**) relative to the chassis **16**. Moreover, when the amount of retraction/extension of each piston rod differs from the other, the front axle **32** may be configured to pivot or oscillate relative to the chassis **16** about the longitudinal axis A. For instance, with retraction of the piston rod associated with the first suspension cylinder **62** and extension of the piston rod associated with the second suspension cylinder **64**, the front axle **32** may pivot or oscillate relative to the chassis **16** in a clockwise direction **74**. Similarly, with extension of the piston rod associated with the first suspension cylinder **62** and retraction of the piston rod associated with the second suspension cylinder **64**, the front axle **32** may pivot or oscillate relative to the chassis **16** in a counter-clockwise direction **76**. Thus, the suspension cylinders **62**, **64** may generally be configured to damp vertical and oscillatory movement of the front axle **32**, thereby enhancing ride quality, reducing operator fatigue and reducing wear on certain components of the work vehicle **10**. Additionally, as will be described below, by actively controlling the operation of the suspension cylinders **62**, **64** while the work vehicle **10** is in the process of turning, the vertical and oscillatory movement of the front axle **32** may be limited in a manner that prevent contact between the front tires **12** and any hood-related components of the vehicle **10**.

Referring now to FIG. **5**, a schematic diagram of one embodiment of a control system **100** for actively determining a steering stop angle for a work vehicle is illustrated in accordance with aspects of the present subject matter. In general, the system **100** will be described herein with reference to the work vehicle **10** and suspension system **30** described above with reference to FIGS. **1-4**. However, it should be appreciated by those of ordinary skill in the art that the disclosed system **100** may generally be utilized with work vehicles **10** having any suitable vehicle configuration and/or any suitable suspension system.

As shown, the control system **100** may generally include a controller **102** configured to electronically control the operation of one or more components of the work vehicle **10**, such as the various hydraulic components of the work vehicle **10** (e.g., the steering cylinders **50**, **52** and/or the suspension cylinders **62**, **64**). In general, the controller **102** may comprise any suitable processor-based device known in the art, such as a computing device or any suitable combination of computing devices. Thus, in several embodiments, the controller **102** may include one or more processor(s) **104** and associated memory device(s) **106** configured to perform a variety of computer-implemented functions. As used herein, the term "processor" refers not only to integrated circuits referred to in the art as being included in a computer, but also refers to a controller, a microcontroller, a microcomputer, a programmable logic controller (PLC), an application specific integrated circuit, and other programmable circuits. Additionally, the memory device(s) **106** of the controller **102** may generally comprise memory element(s) including, but are not limited to, computer readable medium (e.g., random access memory (RAM)), computer readable non-volatile medium (e.g., a flash memory), a floppy disk, a compact disc-read only memory (CD-ROM), a magneto-optical disk (MOD), a digital versatile disc (DVD) and/or other suitable memory elements. Such memory device(s) **106** may generally be configured to store suitable computer-readable instructions that, when implemented by the processor(s) **104**, configure the controller **102** to perform various computer-implemented functions, such as the method **200** described below with reference to FIG. **6**. In addition, the controller **102** may also include various other suitable components, such as a communications circuit or module, one or more input/output channels, a data/control bus and/or the like.

It should be appreciated that the controller **102** may correspond to an existing controller of the work vehicle **10** or the controller **102** may correspond to a separate processing device. For instance, in one embodiment, the controller **102** may form all or part of a separate plug-in module that may be installed within the work vehicle **10** to allow for the disclosed system and method to be implemented without requiring additional software to be uploaded onto existing control devices of the vehicle **10**.

In several embodiments, the controller **102** may be configured to be coupled to suitable components for controlling the operation of the steering cylinders **50**, **52** of the work vehicle **10**. For example, as shown in FIG. **5**, the controller **102** may be communicatively coupled to suitable pressurize regulating valves **107**, **108** (PRVs) (e.g., solenoid-activated valves) configured to regulate the pressure of hydraulic fluid supplied to each steering cylinder **50**, **52**. Specifically, as shown in the illustrated embodiment, the system **100** may include a first PRV **107** for regulating the pressure of the hydraulic fluid supplied to a cap end **110** of each steering cylinder **50**, **52**. In addition, the system **100** may include a second PRV **108** for regulating the pressure of the hydraulic fluid supplied to a rod end **112** of each steering cylinder **50**, **52**.

During operation, hydraulic fluid may be transmitted to the PRVs **107**, **108** from a fluid tank **114** mounted on and/or within the work vehicle **10**. The controller **102** may then be configured to regulate the current commands to each PRV **107**, **108** in order to control the pressure of the hydraulic fluid supplied to each steering cylinder **50**, **52**. Specifically, the current supplied to each PRV **107**, **108** is directly proportional to the pressure supplied to the steering cylinders **50**, **52**, which is, in turn, directly proportional to a stroke length **116** of the piston rod associated with each steering cylinder **50**, **52**. Thus, for example, by increasing the current command to the first PRV **107** and decreasing the current command to the second PRV **108**, the pressure within the cap end **110** of each steering cylinder **50**, **52** may be increased as the pressure within the rod end **112** of each steering cylinder **50**, **52** is decreased, thereby pushing the piston rod outwardly and increasing the stoke length **116**. Similarly, by decreasing the current command to the first PRV **107** and increasing the current command to the second PRV **108**, the pressure within the cap end **110** of each steering cylinder **50**, **52** may be decreased as the pressure within the rod end **112** of each steering cylinder **50**, **52** is increased, thereby pulling the piston rod inwardly and decreasing the stoke length **116**. Thus, by controlling the actuation of the steering cylinders **50**, **52**, the controller **102** may, in turn, be configured to automatically control the associated steering angle of the front tires **12**. As will be described below, such control of the steering angle may allow the controller **102** to prevent the front tires **12** from being rotated beyond their maximum allowable steering angle, thereby ensuring that the tires **12** do not contact one or more hood-related components of the work vehicle **10** as the vehicle **10** is being turned.

In addition, the controller **102** may be configured to similarly control the operation of the suspension cylinders **62**, **64**. For example, in several embodiments, the controller **102** may be communicatively coupled to suitable pressurize regulating valves (PRVs) (e.g., solenoid-activated valves) configured to regulate the pressure of the hydraulic fluid supplied to each cylinder **62**, **64**. Specifically, as shown schematically in FIG. **3**, the controller **102** may be coupled to both a first PRV **150** configured to regulate the pressure of the hydraulic fluid supplied to a rod end **154** of one of the suspension cylinders **62**, **64** and a second PRV **152** configured to regulate the pressure of the hydraulic fluid supplied to a cap end **156** of such cylinder **62**, **64**. In such an embodiment, the current supplied to each PRV **150**, **152** may be directly proportional to the pressure supplied at each end **154**, **156** of the cylinder **62**, **64**, thereby allowing the controller **102** to control the displacement of the cylinder **62**, **64**. It should be appreciated that, although FIG. **3** only illustrates the controller **102** coupled to suitable PRVs for controlling the operation of one of the suspension cylinders **62**, **64**, similar hydraulic components may be utilized to control the other suspension cylinder **62**, **64**. For instance, the controller **102** may be coupled to another pair of PRVs configured to control the pressure of the hydraulic fluid supplied to each end of the other suspension cylinder **62**, **64**, thereby allowing the displacement of each cylinder **62**, **64** to be independently controlled.

Additionally, as shown in FIG. **5**, the controller **102** may be communicatively coupled to one or more input devices **118** for providing operator inputs to the controller **102**. For instance, the controller **102** may be coupled to a control

panel and/or any other suitable input device housed within the operator's cab **18** to allow operator inputs to be received by the controller **102**. As will be described below, such operator inputs may include, for example, one or more tire parameters associated with the front tires **12** installed on the work vehicle **10**.

Moreover, as shown in FIG. **5**, the controller **102** may be communicatively coupled to a plurality of sensors **120**, **122**, **124** for monitoring one or more operating parameters associated with the work vehicle **10**. For example, in several embodiments, the controller **102** may be coupled to a suspension travel sensor **120** for monitoring a suspension travel distance **126** (FIG. **7**) corresponding to the vertical distance defined between a reference location on the front axle **32** and a reference location on the vehicle chassis **16** and/or any other suitable vehicle component. In general, the suspension travel sensor **120** may comprise any suitable sensor and/or combination of sensors that allows for the suspension travel distance **126** of the front axle **32** to be measured directly or indirectly. For instance, in one embodiment, the suspension travel sensor **120** may comprise one or more pressure sensors **128** (FIG. **7**) for monitoring the pressure(s) of the hydraulic fluid supplied within the suspension cylinders **60**, **62**. By monitoring such pressure(s), the stroke lengths of the piston rods associated with each suspension cylinder **60**, **62** may be determined, which may, in turn, allow for the calculation of the suspension travel distance **126**. In another embodiment, the suspension travel sensor **120** may comprise one or more position sensors **130** configured to directly monitor the position of the front axle **32** relative to the chassis **16** or any other suitable component of the work vehicle **10**. For instance, suitable position sensors may include potentiometers, proximity sensors and/or the like.

As shown in FIG. **5**, the controller **102** may also be coupled to an oscillation angle sensor **122** for monitoring an oscillation angle **130** (FIG. **11**) of the front axle **32** relative to a horizontal plane. In general, the oscillation angle sensor **122** may comprise any suitable sensor and/or combination of sensors that allows for the oscillation angle **130** to be measured directly or indirectly. For instance, in one embodiment, the oscillation angle sensor **122** may comprise one or more pressure sensors **128** (FIG. **7**) for monitoring the pressure(s) of the hydraulic fluid supplied within the suspension cylinders **60**, **62**. By monitoring such pressure(s), the stroke length of the piston rod associated with each suspension cylinder **60**, **62** may be determined. Thus, by knowing the horizontal spacing between the steering cylinders **60**, **62**, the oscillation angle **130** of the front axle **32** may then be determined based on the relative displacement of the piston rods. In another embodiment, the oscillation angle sensor **122** may comprise one or more position sensors **130** (FIG. **7**) configured to monitor the position of the front axle **32** relative to the chassis **16** or any other suitable component of the work vehicle **10**, which may then be utilized to determine the oscillation angle **130**. For instance, a first potentiometer may be used to monitor the position of a first portion of the front axle **32** and a second potentiometer may be used to monitor the position of a second portion of the front axle **32**. By knowing the spacing between the potentiometers, the oscillation angle **130** of the front axle **32** may then be determined based on a comparison of the position measurements. In a further embodiment, the oscillation angle sensor **122** may comprise one or more tilt or orientation sensors **132** configured to directly monitor the oscillation angle **130** of the front axle **32**. For instance, suitable orientation sensors may include gyroscopes, accelerometers and/or the like.

Moreover, as shown in FIG. **5**, the controller **102** may also be coupled to a steering angle sensor **124** for monitoring the current steering angle of the front tires **12**. In general, the steering angle sensor **124** may comprise any suitable sensor and/or combination of sensors that allows for the steering angle to be measured directly or indirectly. For instance, in one embodiment, the steering sensor may comprise one or more pressure sensors **134** (FIG. **7**) for monitoring the pressure(s) of the hydraulic fluid supplied within the steering cylinders **50**, **52**. By monitoring such pressure(s), the stroke lengths **116** of the piston rods associated with the steering cylinders **50**, **52** may be determined, which may, in turn, allow for the calculation of the current steering angle of the front tires **12**. In another embodiment, the steering angle sensor **124** may comprise one or more position sensors **136** configured to monitor the current position of the front tires **12** relative to a given reference point, which may then be used to determine the steering angle of the tires **12**. For instance, suitable position sensors may include potentiometers, proximity sensors and/or the like.

It should be appreciated that the controller **102** may also be coupled to any other suitable sensor(s) configured to monitor any other suitable operating parameters of the work vehicle **10**. For instance, in one embodiment, the controller **102** may be coupled to a ground speed sensor (not shown) to allow the controller **102** to monitor the ground speed of the work vehicle **10**.

Referring now to FIG. **6**, a flow diagram of one embodiment of a method **200** for actively determining a steering stop angle for a work vehicle is illustrated in accordance with aspects of the present subject matter. In general, the method **200** will be described with reference to the work vehicle **10** and the system **100** described above with reference to FIGS. **1-5**. However, it should be appreciated by those of ordinary skill in the art that the disclosed method **200** may generally be utilized to actively adjust the steering angle range for work vehicles having any suitable configuration and/or any suitable control system. In addition, although FIG. **6** depicts steps performed in a particular order for purposes of illustration and discussion, the methods discussed herein are not limited to any particular order or arrangement. One skilled in the art, using the disclosures provided herein, will appreciate that various steps of the methods disclosed herein can be omitted, rearranged, combined, and/or adapted in various ways without deviating from the scope of the present disclosure.

It should also be appreciated that the disclosed method **200** will generally be described herein with reference to a hood-related component(s) of the work vehicle **10**. In general, the term "hood-related component" may refer to the hood **28** of the work vehicle **10** and/or any under-hood components of the work vehicle **10**, such as any hydraulic component(s) (e.g., hydraulic lines), pneumatic component(s), electrical component(s) (e.g., electrical wire harnesses), mechanical component(s) (e.g., mechanical drive shafts), storage tank(s), portions of the chassis **16** and/or any other suitable components housed within, installed underneath and/or otherwise positioned vertically below the hood **28**. As will be described below, depending on the arrangement and/or positioning of the "hood-related components" for a given work vehicle **10**, such components may serve to limit the allowable steering angle range for the vehicle.

In general, the disclosed method **200** may be utilized to actively and dynamically determine a maximum allowable

steering angle (i.e., the steering stop angle) to which the front tires **12** of a work vehicle **10** may be rotated at any given point during vehicle operation without contacting one or more hood-related components of the work vehicle **10**. For instance, based on the size and spacing of the front tires **12** as well the front-end configuration of the work vehicle **10** (e.g., the or arrangement and/or positioning of the various hood-related components of the vehicle **10**), a given amount of clearance may be defined between the front tires **12** and any adjacent hood-related components when a specific suspension travel distance **126** and oscillation angle **130** is defined by the front axle **32**, thereby allowing the tires **12** to be rotated to a particular steering angle without contacting the adjacent hood-related component(s). However, as will be described below, changes in the travel suspension distance **126** and/or the oscillation angle **130** may significantly impact the positioning and/or clearance of the front tires **12** relative to the adjacent hood-related component(s). Thus, by monitoring such variables, the system controller **102** may be configured to continuously update the maximum allowable steering angle based on the current positioning of the front tires **12** relative to such adjacent hood-related component(s). This maximum allowable steering angle may then define the steering stop angle to which the steering cylinders **50**, **52** may be allowed to rotate the tires **12** during vehicle operation.

As shown in FIG. **6**, at (**202**), the method **200** includes receiving an input associated with a tire parameter for the front tires **12**. As indicated above, the controller **102** may be configured to receive operator inputs from one or more input devices **118** of the work vehicle **10**, such as a control panel housed within the cab **18**. Thus, in several embodiments, the operator may be instructed to provide an operator input(s) (e.g., via the control panel) associated with one or more tire parameters for the front tires **12**. For instance, in one embodiment, the operator may be instructed to provide inputs associated with the size of the front tires **12**, such as a diameter or height **140** of the front tires **12** (FIG. **7**) and/or a width **142** of the front tires **12** (FIG. **7**), the number of front tires **12** (e.g., a single, dual or triple tire configuration) and/or the spacing of the front tires **12**, such as a tire tread width **144** (FIG. **7**) defined from the center of the left front tire **12** to the center of the right front tire **12**. Upon receipt, such tire parameters may be stored within the controller's memory **106** for subsequent use by the controller **102** as an input for determining the maximum allowable steering angle for the tires **12**.

Additionally, at (**204**), the method **200** includes monitoring the suspension travel distance associated with the front axle. As indicated above, the suspension travel distance **126** (FIG. **7**) may be directly or indirectly measured using a suitable suspension travel sensor **120** (FIG. **5**). The sensor measurements provided by the sensor **120** may then be transmitted to the system controller **102** to allow it to continuously monitor the suspension travel distance **126** during operation of the work vehicle **10**. As will be described below, in addition to defining the vertical position of the front axle **32**, the suspension travel distance **126** may also be associated with or otherwise related to the vertical positioning of the front tires **12** relative to any adjacent hood-related components of the work vehicle **10**. As such, the suspension travel distance **126** may significantly impact the maximum allowable steering angle defined for the tires **12**.

Moreover, at (**206**), the method **200** includes monitoring the oscillation angle of the front axle. As indicated above, the oscillation angle **130** (FIG. **11**) may be directly or indirectly measured using a suitable oscillation angle sensor **122** (FIG. **5**). The sensor measurements provided by the sensor **122** may then be transmitted to the controller **102** to allow it to continuously monitor the oscillation angle **130** during operation of the work vehicle **10**. As will be described below, in addition to defining the angular orientation of the front axle **32**, the oscillation angle **130** may also be associated with or otherwise related to both the vertical and horizontal positioning of the front tires **12** relative to any adjacent hood-related components of the work vehicle **10**. Thus similar to the suspension travel distance **126**, the oscillation angle **130** of the front axle **32** may significantly impact the maximum allowable steering angle defined for the tires **12**.

Referring still to FIG. **6**, at (**208**), the method **200** includes determining a maximum allowable steering angle for the front tires **12** based on both the suspension travel distance **126** and the oscillation angle **130** of the front axle **32**. Specifically, as indicated above, the controller **102** may be configured to receive inputs associated with the size, number and spacing of the vehicle's front tires **12**, thereby providing the controller **102** with reference data related to the positioning of the tires **12** relative to the various hood-related components disposed at the front-end of the work vehicle **10**. Thus, by identifying changes in the suspension travel distance **126** and/or the oscillation angle **130**, the controller **102** may be configured to determine a maximum allowable steering angle to which the front tires **12** may be rotated without contacting any adjacent hood-related component(s) of the work vehicle **10**.

For instance, FIGS. **7-12** illustrate examples in which the maximum allowable steering angle determined by the controller **102** may vary based on the suspension travel distance **126** and/or the oscillation angle **130** of the front axle **32**. Specifically, FIGS. **7** and **8** illustrate front and top schematic views, respectively, of the front axle **32** and the front tires **12** of a work vehicle **10**, particularly illustrating the positioning of the front tires **12** relative to a hood-related component **180** of the work vehicle **10**. FIGS. **9** and **10** illustrate front and top schematic views, respectively, of the front axle **32** and front tires **12** shown in FIGS. **7** and **8** after the suspension travel distance **126** of the front axle **32** has changed, thereby altering the positioning of the front tires **12** relative to the hood-related component **180**. Additionally, FIGS. **11** and **12** illustrate front and top schematic views, respectively, of the front axle **32** and front tires **12** shown in FIGS. **7** and **8** after the oscillation angle **130** of the front axle **32** has changed, thereby altering the positioning of the front tires **12** relative to the hood-related component **180**.

As shown in FIG. **7**, at a given suspension travel distance **126** and at a zero oscillation angle, the front tires **12** may, for example, be positioned relative to a hood-related component **180** of the work vehicle **10** such that the tires **12** vertically overlap the hood-related component by a vertical length **182**. Due to such vertical overlap, the front tires **12** may be configured to contact the hood-related component **180** as the tires **12** are rotated clockwise or counter-clockwise relative a vertical reference plane **184** defining the zero steering angle position for the tires **12**. For instance, as shown in FIG. **8**, when positioned at a zero steering angle (indicated by the solid lines), the front tires **12** may be spaced horizontally from the hood-related component by a horizontal length **186**. However, as the front tires **12** are rotated away from this zero steering angle position, the horizontal length **186** may be reduced until the tires **12** contact the hood-related component **180**. For instance, as shown in FIG. **8**, the front tires **12** may be configured to contact the hood-related

component **180** when moved to a steering angle **188** defined relative to the vertical reference plane **184**. Thus, in order to maintain clearance between the front tires **12** and the hood-related component **180** during vehicle operation, a maximum allowable steering angle may be selected for the front tires **12** that corresponds to a steering angle that is less than the steering angle **188**, such as a steering angle that is equal to about 90% of the steering angle **188** or about 95% of the steering angle **188** or about 99% of the steering angle **188**.

Alternatively, in the example shown in FIGS. **9** and **10**, the suspension travel distance **126** for the front axle **32** has been increased as compared to that shown in FIGS. **7** and **8** such that the front tires **12** no longer vertically overlap the hood-related component **180**. For instance, as shown in FIG. **9**, a vertical clearance **190** is defined between the front tires **12** and the hood-related component **180**. As such, when adjusting the steering angle, the tires **12** may be rotated below the hood-related component **180** to a steering angle **192** that is greater than the steering angle **188** shown in FIG. **10**. In such instance, instead of being limited by the hood-related component **180**, the maximum allowable steering angle may be selected based on the positioning of the front tires **12** relative to any other suitable hood-related components of the work vehicle **10** and/or based on the capabilities of the steering assembly (e.g., the maximum allowable stoke for the steering cylinders **50**, **52**).

Similarly, in the example shown in FIGS. **11** and **12**, the front axle **32** has been pivoted or otherwise oscillated in the clockwise direction as compared to that shown in FIGS. **7** and **8** such that the front axle **32** defines a non-zero oscillation angle **130**. Thus, in addition to vertically overlapping the hood-related component **180** by a given vertical length **194**, the horizontal length **196** defined between the left front tire **12** and the hood-related component **180** at the zero steering angle position has been significantly reduced. As such, the front tires **12** may be configured to contact the hood-related component **180** at a steering angle **198** that is less than the steering angle **188** described above. Thus, in order to maintain a clearance between the front tires **12** and the hood-related component **180**, a maximum allowable steering angle may be selected for the front tires **12** that corresponds to a steering angle that is less than the steering angle **198**, such as a steering angle that is equal to about 90% of steering angle **198** or about 95% of the steering angle **198** or about 99% of the steering angle **198**.

It should be appreciated that FIGS. **7-12** are illustrated simply to provide examples of how the maximum allowable steering angle may vary depending on the suspension travel distance **126** and the oscillation angle **130** of the front axle **32**. However, those of ordinary skill in the art should readily appreciate that the maximum allowable steering angle for a work vehicle **10** at a given suspension travel distance **126** and oscillation angle **130** may generally vary from work vehicle to work vehicle depending on the front end configuration of the vehicle **10** (e.g., the arrangement and positioning of the various hood-related components of the vehicle **10**) as well as the size, number and spacing of the front tires **12**.

Thus, it should be appreciated that, in several embodiments, computer modeling and/or physical testing may be performed to collect data that relates the maximum allowable steering angle to both the suspension travel distance **126** and the oscillation angle **130** for a given vehicle configuration. For instance, in one embodiment, a three-dimensional model of the front end of a work vehicle **10** may be created that allows the tire size and number, tire spacing, suspension travel distance **126** and oscillation angle **130** to be varied. In such an embodiment, by analyzing the available clearance defined between the front tires **12** and the relevant hood-related components at each potential combination of tire size, tire spacing, suspension travel distance and oscillation angle, a mathematical relationship(s) and/or a look-up table(s) may be developed that relates such variables to the maximum allowable steering angle. This relationship(s) and/or look-up table(s) may then be stored within the controller's memory **106** and subsequently utilized to determine the maximum allowable steering angle based on the operator inputs and sensor measurements received by the controller **102**.

Referring back to FIG. **6**, at **210**, the method **200** includes controlling the operation of the steering cylinders **50**, **52** of the work vehicle **10** based on the maximum allowable steering angle. Specifically, in several embodiments, the controller **102** may be configured to control the operation of the steering cylinders **50**, **52** in a manner that prevents the front tires **12** from being rotated beyond the maximum allowable steering angle. As indicated above, such control of the steering cylinders **50**, **52** may be achieved by regulating the current command transmitted to the associated PRVs **107**, **108**, which, in turn, controls the pressure of the hydraulic fluid supplied to the cylinders **50**, **52**. Thus, by limiting the maximum pressure that can be supplied to each steering cylinder **50**, **52** based on the maximum allowable steering angle, the tires **12** may be prevented from being rotated beyond the maximum allowable steering angle

Additionally, as indicated above, the controller **102** may also be configured to actively control the operation of the suspension cylinders **62**, **64** to account for changes in the suspension travel distance **126** and/or the oscillation angle **130** that may result in contact between the front tires **12** and any adjacent hood-related components. For example, a work vehicle may enter a turn with the front tires **12** rotated to a steering angle that is less than the maximum allowable steering angle determined for the current suspension travel distance **126** and oscillation angle **130** of the front axle **32**. However, during the turn, it may be possible for the suspension travel distance **126** and/or the oscillation angle **130** to vary in a manner that would cause the front tires **12** to contact one or more adjacent hood-related components, even without any change to the tires' steering angle. In such instance, the operation of the suspension cylinders **62**, **64** may be controlled so as to prevent any changes in the suspension travel distance **126** and/or the oscillation angle **130** that would cause such contact. For instance, if a further decrease in the suspension travel distance and/or a further increase in the oscillation angle would result in contact between the tires and any hood-related components, the controller may be configured to control the operation of the cylinders **62**, **64** in a manner that limits such further changes.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they include structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A method for actively determining a steering stop angle for tires associated with a front axle of a work vehicle, the method comprising:

receiving, with a computing device, an input associated with a tire parameter for the tires;

monitoring, with the computing, device, a current suspension travel distance of the front axle, the suspension travel distance being associated with a vertical position of the tires relative to at least one hood-related component of the work vehicle;

monitoring, with the computing device, a current oscillation angle of the front axle, the oscillation angle being associated with at least one of the vertical position or a horizontal position of the tires relative to the at least one hood-related component;

dynamically determining, with the computing device, a maximum allowable steering angle for the tires based on both the current suspension travel distance and the current oscillation angle of the front axle, the maximum allowable steering angle corresponding to a steering angle at which clearance is maintained between the tires and the at least one hood-related component when the tires are positioned at the maximum steering angle; and

actively controlling, with the computing device, an operation of a steering cylinder associated with the front axle based on the dynamically determined maximum allowable steering angle.

2. The method of claim 1, further comprising receiving, with the computing device, measurement signals associated with the current suspension travel distance of the front axle from a first sensor communicatively coupled to the computing device.

3. The method of claim 2, wherein the first sensor comprises at least one of a pressure sensor configured to measure a pressure of hydraulic fluid supplied to a suspension cylinder of the work vehicle or a position sensor configured to measure a relative position of the front axle.

4. The method of claim 1, further comprising receiving, with the computing device, measurement signals associated with the current oscillation angle of the front axle from a second sensor communicatively coupled to the computing device.

5. The method of claim 4, wherein the second sensor comprises at least one of a pressure sensor configured to measure a pressure of hydraulic fluid supplied to a suspension cylinder of the work vehicle, a position sensor configured to measure a relative position of the front axle or an orientation sensor configured to measure an angular orientation of the front axle.

6. The method of claim 1, wherein dynamically determining the maximum allowable steering angle comprises continuously updating the maximum allowable steering angle based on changes in at least one of the current suspension travel distance or the current oscillation angle of the front axle as the work vehicle operated.

7. The method of claim 1, wherein the at least one hood-related component comprises at least one of a hood of the work vehicle or an under-hood component of the work vehicle.

8. The method of claim 1, wherein the tire parameter comprises at least one of a tire size of the tires or a tire tread width associated with the tires.

9. The method of claim 1, further comprising controlling, with the computing device, an operation of a suspension cylinder of the work vehicle to account for changes in at least one of the current suspension travel distance or the current oscillation angle while the work vehicle is being turned.

10. A system for actively determining a steering stop angle for tires associated with a front axle of a work vehicle, the system comprising:

a steering assembly configured to rotate each of the tires relative to the front axle, the steering assembly including a first steering cylinder and a second steering cylinder;

a controller configured to control an operation of the first and second steering cylinders, the controller including a processor and associated memory, the memory including computer-readable instructions that, when implemented by the processor, configure the controller to:

receive an input associated with a tire parameter for the tires;

monitoring a current suspension travel distance of the front axle, the suspension travel distance being associated with a vertical position of the tires relative to at least one hood-related component of the work vehicle;

monitor a current oscillation angle of the front axle, the oscillation angle being associated with at least one of the vertical position or a horizontal position of the tires relative to the at least one hood-related component;

dynamically determine a maximum allowable steering angle for the tires based on both the current suspension travel distance and the current oscillation angle of the front axle, the maximum allowable steering angle corresponding to a steering angle at which a clearance is maintained between the tires and the at least one hood-related component when the tires are position at the maximum steering angle; and

actively control the operation of at least one of the first steering cylinder or the second steering cylinder based on the dynamically determined maximum allowable steering angle.

11. The system of claim 10, further comprising a first sensor communicatively coupled to the controller, the first sensor being configured to transmit measurement signals to the controller associated with the current suspension travel distance of the front axle.

12. The system of claim 11, wherein the first sensor comprises at least one of a pressure sensor configured to measure a pressure of hydraulic fluid supplied to a suspension cylinder of the work vehicle or a position sensor configured to measure a relative position of the front axle.

13. The system of claim 10, further comprising a second sensor communicatively coupled to the controller, the second sensor being configured to transmit measurement signals to the controller associated with the current oscillation angle of the front axle.

14. The system of claim 13, wherein the second sensor comprises at least one of a pressure sensor configured to measure a pressure of hydraulic fluid supplied to a suspension cylinder of the work vehicle, a position sensor configured to measure a relative position of the front axle or an orientation sensor configured to measure an angular orientation of the front axle.

15. The system of claim 10, wherein the controller is configured to dynamically determine the maximum allowable steering angle by continuously updating the maximum allowable steering angle based on changes in at least one of

the current suspension travel distance or the current oscillation angle of the front axle as the work vehicle operated.

16. The system of claim **10**, wherein the at least one hood-related component comprises at least one of a hood of the work vehicle or an under-hood component of the work vehicle.

17. The system of claim **10**, wherein the tire parameter comprises at least one of a tire size of the tires or a tire tread width associated with the tires.

18. The system of claim **10**, wherein the controller is further configured to control an operation of a suspension cylinder of the work vehicle to account for changes in at least one of the current suspension travel distance or the current oscillation angle while the work vehicle is being turned.

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